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SEXUALITY IN MUCORS[1]

The keywords of the vice-president's address and the symposium which followed it last year were *Organization, Coordination* and *Cooperation* in botanical research. It is not my purpose at this time to discuss these topics further. A botanical committee of the National Research Council has been selected for this purpose. A second committee was chosen by the Botanical Society of America two years ago to help the first committee and last year a third committee was appointed to help the other two. The organization seems sufficiently complete unless I might suggest as a humble member of this last-named committee that a new committee be formed at this session to help us also in our deliberations which have not as yet taken place.

One of last year's speakers, in distinguishing types of true research worth while from investigations unworthy of the name, held up to ridicule a hypothetical investigation of a ham sandwich and the pseudo-scientist who would attempt a monographic treatment of such a subject. In defence of the maligned sandwich, a correspondent has offered the following lines:

> Sandwich perched by the lunchroom wall,
> I lift you down from the perches.
> Hold you here, ham and all, in my hand.
> Little sandwich! But if I could understand
> What you are, ham and all, and all in all,
> I should know what true research is.

It is not of so broad a subject as the sandwich in its entirety, neither of the ham nor of the bread between which it nestles that I wish to speak. Rather it is the mold that sometimes grows on the bread that encircles the ham, or more especially the less commonly

[1] Address of the vice-president and chairman of Section G, Botany, American Association for the Advancement of Science, St. Louis, December 30, 1919.

observed sexual reproduction of the bread mold and its relatives that I have chosen as my theme.

It will not be possible in the time available to enter into any detailed discussion of many questions that might suggest themselves in this connection. I shall instead give an outline merely of some of the investigations of the last fifteen years, both published and unpublished and shall attempt to show that the sexual relations of the mucors may have possible bearings upon our conceptions of sexuality in other diverse groups of the biological world.

The chart (9, Tafel VI.)[2] shows the typical vegetative condition of a mucor. A vegetative spore, usually multinucleate though sometimes uninucleate, sends out in germination a branching tube which forms the mycelium and rapidly covers the available substratum. This mycelium is multinucleate and, in the early stages at least, without cross walls—forming thus an enormous, much-branched, single cell—if a cell is defined in terms of the limiting cell walls. Multiplication is brought about chiefly by various types of nonsexual spores. The commonest are endogenous spores produced in sporangia, upwards of 70,000 individual spores being formed in a single sporangium. They may be apparently exogenous, formed singly or in chains on terminal swellings of fertile filaments and may be produced as chlamydospores by septation of the vegetative filaments. More than a single type of nonsexual multiplication may occur in a given species.

As regards their sexual reproduction, there are two groups of species. In the first group, represented by *Sporodinia,* a form common on fleshy fungi, the sexual spores known as zygospores are common and may be obtained from the sowing of a single vegetative spore. Such forms are therefore hermaphroditic or homothallic since their thalli or mycelia are alike sexually. In the second group, represented by *Rhizopus,* the bread mold, the zygospores are rarely observed and can never be obtained in pure cultures from the sowing of a single spore. In these diecious or heterothallic forms there are needed two plants of opposite sex growing in contact in order that sexual reproduction may take place. The two sexual groups mentioned are represented in the adjoining diagram (Fig. 4). Since in the three lower figures the two gametes (which later unite to form the mature zygospore) arise from branches of a single filament, these three forms are hermaphroditic. In the upper figure the gametes are represented arising from sexually different plants designated by the signs plus and minus which will be explained later. These therefore belong to the diecious group. The line of zygospores, which results when the opposite sexes of the diecious species *Mucor Mucedo* are grown in contact, is shown in the chart. The swollen heads produced on erect filaments from the plant on the right of the line are sporangia containing numerous nonsexual spores by which the plant may be propagated as distinct sexual races in much the same manner in which races of potatoes may be propagated by non-sexual tubers. The process of conjugation may be followed from the figures in the chart (9, Tafel VII.). Filaments of opposite sexual tendencies grow together and by the stimulus of contact produce swellings which push them apart. These swellings develop into the *progametes* from which by cross walls the sex cells, or gametes, are cut off. The dissolution of the intervening cross wall allows a fusion of the gametes and the zygote thus formed increases in size and becomes the mature zygospore. The gametes are typically equal in size in the diecious group and also in the hermaphroditic group except for certain forms to be discussed later. They are miltinucleate and hence have been called cœnogametes.

In the first lantern slide (1, Pl. IV.), we can see photographs of Petri dish cultures of certain of the mucors experimented with. The opposite sexes of the diecious species have been termed plus and minus for reasons

[2] Citations in parentheses throughout the text refer to the sources for the charts and lantern slides used in the original presentation of this paper.

to be explained shortly. By inoculating plus and minus spores in appropriate spots in the culture dish definite patterns may be obtained by the lines of zygospores formed where the opposite sexes meet as shown in Figs. 52–55.

IMPERFECT HYBRIDIZATION

It was soon established that in any given diecious species there are only two sexes present but at first there was no assurance that the two sexes of a given species were the same as those of any other. It has been discovered, however, that the opposite sexes of different species are capable of showing an imperfect sexual reaction when grown in contact. The photograph on the screen (Fig. 1,

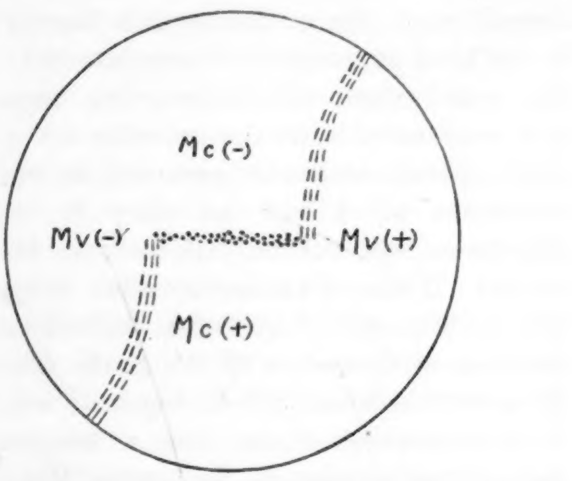

FIG. 1. Diagram of Petri dish culture showing zygospores (dots) between the (+) and (—) races of the same species, *Mucor* C and lines of "imperfect hybridization" (dashes) at contact between opposite sexes of different species, *Mucor* C and *Mucor* V.

which is taken from photograph in 7) represents a culture of the sexual races of two different species *Mucor* V and *Mucor* C.

Where the two sexes of *Mucor* C meet a line of zygospores is evident as might be expected. The sexual race of *Mucor* V on the right shows a reaction only with *Mucor* C minus as indicated by the white line where the two meet and must be considered the opposite sex from *Mucor* C minus, or plus. In like manner the other sex of *Mucor* V on the left shows a reaction only with the plus race of *Mucor* C and must therefore be considered minus. A microscopic investigation of the appearance of the white lines of sexual reactions shows the condition represented in Figs. 36–39 (1). The stimulus of contact leads to the formation of progametes. Sometimes the gamete is formed by one and more rarely by both the reacting filaments. In one strong reacter the gamete which is formed in this reaction transforms itself frequently into a thick-walled a-zygospore. The stimulus which leads to a dissolving away of the wall between the two gametes and their consequent fusion is constantly lacking. Since the sexual reaction between opposite sexes of different species is incomplete it has been termed "*imperfect hybridization.*"

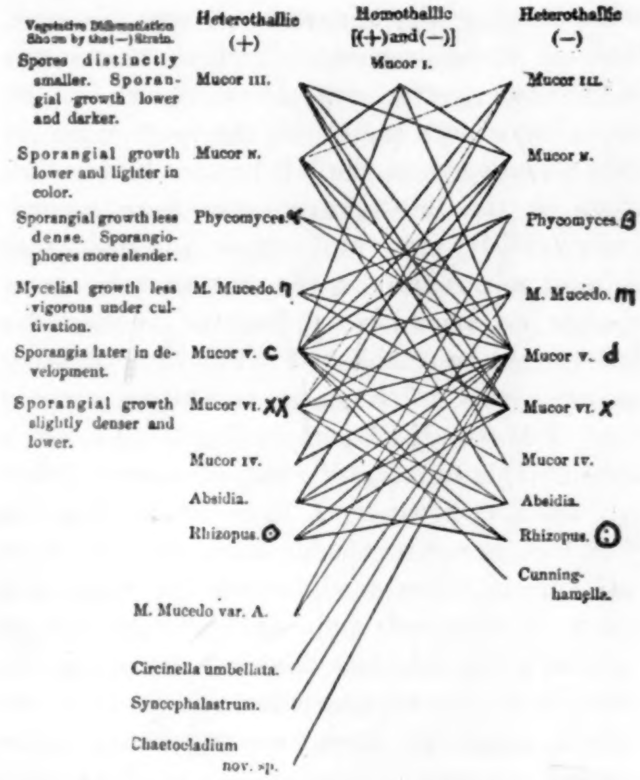

FIG. 2. "Imperfect hybridization" reactions shown by solid lines between sexual races of different species.

At first the paired races of different species were designated by letters and symbols. Lines in the diagram (Fig. 2) indicate some of the reactions that have been obtained between races of different species. All races that show a reaction with the "c" race of *Mucor* V used as a standard but not with its "d" race, are placed in the right column,

while those that show a reaction with the "d" race of *Mucor* V and not with its "c" race are placed in the left column. In no case has the position of any of the races been determined by less than two positive reactions. Any race in the left column is theoretically capable of showing a reaction with any in the right column, while incapable of reacting with those in its own group and vice versa. Certain combinations, however, react with greater difficulty than others. It is obvious that in these two columns we have represented the two opposite sexes, male and female. There seemed, however, no way of determining which is to be considered male and which female since their gametes are typically equal in size.

In making the diagram, it was observed that of those species, in which there was evident a greater vegetative vigor of one sexual race over the other, the more vigorous race was always in the left-hand column. All those in the left-hand column were accordingly called plus and those in the other column minus despite the fact that in many species no vegetative difference between the sexes could be established. The most striking example of a difference in vegetative vigor is that of *Mucor* III shown in Fig 58 (1). In a considerable number of races in several different species, however, I have found that the plus race is not invariably more vigorous than the minus when a difference in vegetative vigor is observed, judging vigor by former criteria; but this fact does not detract in the least from the evidence that in the plus and minus races we have the two sexes represented.

The "imperfect hybridization" reaction is of convenience in determining the sex of unmated races. Thus when the diagram (Fig. 2) was made, a race of *Circinella umbellata* obtained from a curbstone in the shadow of Harvard University, by reacting with *Mucor* V plus and failing to react with *Mucor* V minus, was found to be a minus race and is so listed in the diagram. Later a race was obtained from a substratum sent by a missionary from China and was discovered to be its plus mate. It was a relatively easy matter then to obtain the zygospores by uniting these opposite races under suitable nutrient and temperature conditions. The last species in the minus column was found in 1903 in a culture of rat's whiskers gathered on an island in the Caribbean Sea. Perhaps somewhere, under some spreading palm, from India's coral strand, its mate is waiting; and another good missionary may help in spreading the gospel of a "form new to science."

I said a moment ago that it is theoretically possible to obtain an "imperfect hybridization" reaction between the sexual race of a given species and the opposite sexual race of any other species. In practise it has not always proved easy of accomplishment. Much depends upon the environmental factors such as the kind of nutrient—more, however, upon the sexual vigor of the reacting races. A race may react with the opposite sex of another species under temperature or nutrient conditions which will not allow it to form zygospores with its normal mate in its own species. Thus *Cunninghamella echinulata* will readily give "imperfect hybridization" reactions with species of the genus *Mucor* at temperatures below 20° C. but will not itself form zygospores at so low a temperature, while some species of the genus *Mucor* are weak in reaction when contrasted *inter se*. The vigor of the reaction, therefore, has no apparent connection with the taxonomic relationships of the forms involved. Cunninghamella it may be remembered is so distantly related to the genus *Mucor* that it was originally described as a Hyphomycete and assumed to belong to a group of fungi unrelated to the mucors.

Saito and Naganishi (13) report obtaining true hybrid zygospores between different *Mucor* species. They admit, however, that the species in question are very closely related. I have found, between what I have called the opposite sexes of a single species, differences sufficiently marked to be worthy of description as distinct species according to Bainier who has been one of the mycologists most prolific in fathering *Mucor* species. I,

as well as others, have observed also considerable differences between the different strains of a single sex of a given species. It is possible that these Japanese investigators have been dealing with races with differences of the order just mentioned. The matter may be a question of what is a species. Burgeff, however, in his brilliant investigations of Phycomyces (10), has obtained a striking distinct mutant which he has been able to cross successfully with the normal stock.

It seems strange that the reaction initiated in the process of "imperfect hybridization" is, usually at least, unable to carry through to completion. We can assume something fundamental, common to all the plus races of the various mucor species, that causes a response when they are brought into contact with a minus race and something in addition that must be present peculiar to the same species in order to extend the reaction to a union of gametes and their development into normal zygospores.

These fundamental characteristics of plus and minus must be present also in the hermaphroditic or homothallic species since, as indicated at the top of Fig. 2, such hermaphroditic species may show sexual reactions with plus and minus races used as testers. The reaction is often strong enough to be indicated by white lines as shown in Fig. 56 (1) where the hermaphroditic *Mucor* I is reacting with both plus and minus races of *Mucor* V.

ZYGOSPORE GERMINATION

It will be of interest to note what occurs at the germination of zygospores formed by the sexual races. A zygospore at germination produces a short germ-tube, terminated by a germ sporangium. The condition is represented diagrammatically on the screen (4). In the hermaphroditic species investigated, all the spores in the germ sporangium are hermaphroditic and give rise to hermaphroditic plants as is to be expected. In the diecious species, however, there are two types of zygospore germination. In *Mucor Mucedo* the spores in a germ sporangium are all of the same sex—plus *or* minus, never mixed. In *Phycomyces,* on the other hand, the germ sporangium may contain spores of both sexes. The germ tube may be induced to grow out vegetatively before the formation of its germ sporangium. By this means its sexual condition can be tested. The germ tube of *Mucor Mucedo* has been found to be unisexual, of the same sign as its germ sporangium. Segregation or differentiation of sex in this species, therefore, must have taken place at or before the zygospore germinates. In *Phycomyces* sexual differentiation takes place in the germ sporangium and induced growth from a germ tube gives rise to a temporarily hermaphroditic condition. Such a hermaphroditic or homothallic mycelium is shown in the photograph (2). Its yellowish felted growth is strikingly different from the normal plus and minus races which are forming a line of zygospores where they meet at the upper right-hand corner of the culture. Occasionally spores in the germ sporangium of *Phycomyces* are hermaphroditic and produce such hermaphroditic mycelia. Burgeff has ingeniously produced them by mechanically mixing the protoplasm of plus and minus vegetative filaments and has given them the name of mixochimæras. He concludes that such mixochimæras are mixtures of plus and minus nuclei. That these sexual mixochimæras are bisexual is shown by their occasional production of hermaphroditic zygospores and by the fact that the scanty sporangia which they produce again divide up into plus and minus and occasionally hermaphroditic spores. Often they show a plus or a minus tendency by forming zygospores with the normal minus or plus test races of *Phycomyces.* If propagated by cuttings of the mycelium, they eventually revert to normal plus or minus races.

The diagram (4) has been shown in order to point out certain homologies between sexual differentiation in the mucors and that in other groups of plants. The mucor plant is the gametophyte, the flowering plant the sporophyte. The germ tube with its germ sporangium we have homologized with the sporophyte and Burgeff reports in *Phycomyces*

a fusion of nuclei in pairs in the zygospore and a reduction division in the germ sporangium preceeding the formation of the spores. From the diagram it will be observed that the condition in the so-called hermaphroditic lily is homologous with that in the so-called diecious *Phycomyces* or *Marchantia* in which I have found a similar differentiation of sex in sporophytic sporangia. The forms just mentioned are of the same type of sexual differentiation and yet are termed hermaphroditic or diecious according to whether the sporophyte or the gametophyte is the more conspicuous. To insure greater precision, I have suggested the terms homo- and hetero-thallic as applied to the gametophyte and homo- and hetero-phytic as applied to the sporophyte. If in further discussion of the subject, I use the older terminology, it is only to avoid terms unfamiliar to the majority of my audience. The main point to be brought out is that diecious mucors are not to be homologized with diecious flowering plants and higher animals. More nearly are the sexual races of mucors to be compared with the gametes themselves of such higher plants and animals.

ENVIRONMENTAL FACTORS

Many investigators have succeeded in inhibiting the expression of one or both sexes on the gametophyte of ferns by varying the environmental factors to which they are exposed. The question arises as to the influence of environmental factors on sexuality in the mucors. Since gametes are formed only *after* the stimulus of contact between filaments with opposite sex tendencies and not independently, the question is reduced to the influence of external factors on zygospore formation and upon the sexual activity of the separate races. As a general rule, both for hermaphroditic and diecious forms it may be said that the limits within which zygospore formation is possible are narrower than those for non-sexual reproduction. Thus in *Cunninghamella echinulata,* non-sexual reproduction takes place in abundance at low and high temperatures while zygospores are formed only above 20° C. Certain other species will not form zygospores, although able to produce sporangia at a temperature as high as 26° C. Further examples of other factors than temperature might be given in support of the greater environmental requirements necessary for the sexual type of reproduction. So far as has been investigated, external factors have no influence in altering the inherent sex character in a given race, though they may change its power of showing a sexual response.

The plus and minus races of *Phycomyces* have been cultivated in separate test-tubes since 1903 and have now reached the 242d non-sexual generation of both plus and minus races. The plus and minus races of *Mucor Mucedo* have been cultivated for the same length of time. The minus race has gradually become weaker and has this year finally died out. There does not seem to have been any actual loss or change of sex in the process although the ability to respond sexually has weakened with the weakness of vegetative growth.

MUTATIONS

It is a question whether or not it will ever be possible to induce genetic changes in the mucors by changes in environmental factors. Such changes do occur in some forms, however, apparently spontaneously. In 1912–13, in an investigation as yet unpublished, I found numerous variants of various degrees of distinctness in the offspring of a single plant obtained by sowing non-sexual spores. Three forms from the hermaphroditic species *Mucor genevensis* will suffice in illustration. In the roll tube at the right is shown a number of mycelium colonies of a dwarf mutant. They are of about the same age as those in the tube at the left. The dwarf has no sporangia but is propagated by divisions of the thallus. Perhaps the weakness of its growth is responsible for the fact that it does not form zygospores as other races of this species do.

At the right of the Petri dish culture (Fig. 3) are shown two colonies of the normal parent race. The small dots scattered over the surface are zygospores formed by the hermaphro-

dite. (The large circles in the culture are the places where the races were inoculated.) Tests with plus and minus races show that this normal race is a hermaphrodite with a minus tendency. In the central vertical row, three colonies are growing of a mutant with a plus tendency. That it is also hermaphroditic is shown by the dark dots representing zygospores which it produces, larger and arranged

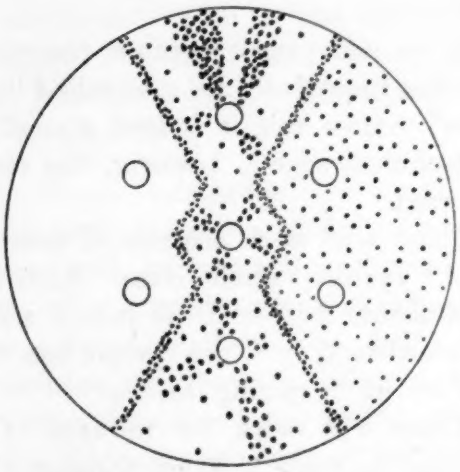

FIG. 3. Diagram of Petri dish culture of the hermaphroditic species *Mucor genevensis*. Circles represent points of inoculation, dots represent zygospores. Two colonies at right represent the normal parent stock; vertical row in center represents three colonies of a mutant with a (+) tendency; two colonies at left represent a mutant with (—) tendency.

in sectors more often than in the parent race. Since it has an opposite sexual tendency from the normal race, it forms a line of zygospores where it grows in contact with it. It also is forming a line of zygospores with the mutant on the left, two colonies of which are shown. This last mentioned mutant has, like its normal parent form, a minus tendency. Aside from its dense yellow growth, it is characterized by its well-nigh complete suppression of hermaphroditic zygospores on its own mycelium. If the suppression were complete and the race constant, we might be able to describe the origin of a diecious race from a hermaphroditic species. With the exception of the dwarf mutant which has been kept running since 1913, but which does not produce sporangia, and another possible exception, all the mutant variants found in this species eventually reverted to the normal type.

The tendency to reversion has been observed by Burgeff in his mutants of *Phycomyces* and attributed by him to a more rapid growth of the normal nuclei over the mutant nuclei in mixochimæras which he considers such variants to be. He was able to bring his mutants into a true-breeding condition by crossing them with the normal stock of opposite sex and obtaining the desired purity through segregation in the germ sporangia. Sex and mutant characters he found to segregate independently so that starting with a mutant in a plus race he was able eventually to obtain it in the minus condition.

DISTRIBUTION OF SEXUAL TYPES IN NATURE

A study has been made of the distribution in nature of the different sexual types. So far as the number of species is concerned, the diecious or heterothallic forms greatly predominate. If the table on the screen (5) were made to-day, we probably should have to more than double the list of species definitely known to have been mated. If unmated strains with sex determined by the "imperfect hybridization" reaction were added, the number would be still further increased. Of the homothallic (hermaphroditic) forms, very few would have to be added and the hermaphroditic forms it will be observed are those in which the sexual condition is readily determined by mere microscopic inspection and their zygospores therefore less likely to escape notice.

Table II. (3) above shows the distribution of races of *Rhizopus* obtained from different sources. As will be seen, the sexual strains are not at all local in their distribution. Those listed as neutral failed to give any reaction with the plus and minus test races. More extensive tests have recently been made with *Rhizopus* and other species as will appear in a later summary.

Collections of races of several different species have been made from diverse sources and the races within a given species tested for reactions *inter se*. Perhaps a form provi-

sionally called "Dark" Absidia will serve as a convenient example. The collection of this species consists of 40 races. They have been contrasted with one another by twos in watch-glass cultures and all the possible combinations have been made as shown in the table. Grades A to D were assigned to the different strengths of sexual reaction measured by the number of zygospores produced in a given contrast. Each race was given a final numerical grade made up of the average of its reactions with all the other races and the races were arranged in the table according to their final grading. The plus and minus races were placed in series by themselves. There was no reaction when a plus was contrasted with another plus nor when a minus was contrasted with another minus. Whether they were of equal sexual vigor or one was weak and the other strong, the result of contrasting two races with the same sign was always negative. The collection of races therefore seemed dimorphic so far as sex is concerned. A race was either shown to be plus or minus or showed no reaction in a given combination and was provisionally classed as "neutral." There were no races evident that could be called sex intergrades.

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(*To be concluded*)

AN ANALYSIS OF AIM AND INCENTIVE IN A COURSE IN GENERAL ZOOLOGY

INCENTIVE AND AIM

That an incentive is necessary for the accomplishment of work is a postulate that needs no discussion. A review of my work as a teacher has led me to investigate the incentives that activate my students—mostly freshmen plunged into a course in general zoology. I have felt for some time that the aim of the course did not furnish an incentive for work.

Aim is confused with incentive because in some cases the two are equivalent. Aim is an aspiration for an ideal while incentive is an earthly motive. The statement of an aspiration may form an incentive for a few; but for most students the aim is soon forgotten.

INCENTIVE OF STUDENTS IN GENERAL ZOOLOGY

Since the motive that actually completes the work is not the aim, it is worth while to inquire what is the incentive. I recognize that the material with which I have to do shows a great deal of individual variation. In this "population" four classes can be discerned.

1. Those who work because the aim furnishes the incentive. In a so-called "general culture" course this is indeed a small class; in a technical school, however, the condition is reversed.

2. Those who work because of love for the subject, another small class. Although in some students this desire is inborn and probably hereditary, yet the proportion can be raised by an inspiring teacher.

3. Those who work for rewards. Our institutions, in their wisdom, through years of experience, have devised grades and honors. Some students have an inborn and probably hereditary ambition to seem better than their fellows and so react to this stimulus. Indeed competition can furnish a splendid incentive.

4. Those who work through fear. The same machinery erected to appeal to the ambitious reacts to prod the laggard. Under the threat of probation, condition, and exclusion, the victim struggles on. This is a large class and, in some ways, the most interesting. Although this group contains the dullards, yet the ranks are far from being homogeneous—the most brilliant member of the class may be buried in its ranks. How often have we seen a student, who, by constant threats, has just managed to scramble through our course, enter a technical school and not only lead his class but in time his profession. Lack of incentive is the key to his attitude toward the course in zoology. Being a more reasoning being than his fellows who work for love or rewards, and, feeling that the aim did not furnish an incentive, he gave his energies where, to his mind, results would be of more value.

THE AIM OF A COURSE IN GENERAL ZOOLOGY

It would be futile to list all the aims of a course in general zoology since two stand out in such bold relief that all others are cast into the shadow. These two are as follows:

1. To teach *science* which will give the student the method to gather zoological information and to use it.

2. To direct him to gather such information that will make him understand himself and his environment which in the end will make him review his moral and social responsibilities, leading to an intelligent selection of action in after life.

SCIENCE

These aims hinge on definitions and no definition will have more influence on the conduct of a course than the definition of science. Those teachers who define science as *knowledge* will have a different aim for their course than those who define science as *method*. While the students of the first class will get much information pumped into them they will get little training in method. Science, defined by Huxley as "common sense at its best," or organized common sense, can be analyzed as follows:

2. We observe (experiment).

3. We record our observations (experiments) clearly described in an *organized* form that others may repeat and confirm them.

4. We draw conclusions, at the same time discussing the results of others that have come within our experience.

Zoologists, botanists and even chemists feel that they have so much information to impart that they quite forget to teach science in the elementary course. It fell to the lot of the writer to get his first training in science out of a course of history. A problem was set, original sources of history were supplied, the data recorded, and conclusions drawn. Because his science teachers held that science was knowledge they made the imparting of information the most important aim.

OBSERVATION

To see one must be trained to see. He who is brought up on a diet of books alone is apt to be as "blind as a bat." As President Eliot and others have repeatedly pointed out, biology is preeminent among sciences in giving training in observation. Training in observation, therefore, is an important aim in a course in general zoology

THE RECORD

To record observations two methods of description are available, descriptions in words and descriptions by drawings. The former includes logical arrangement of matter organization and the clear use of the English language. Where the objects or processes to be described are complicated, words alone are too cumbersome, so the graphic method supplies a short-hand method of accurate description. Drawing is not an end in itself. It is not used as in art to express the impression of an object, but to indicate relationships that can not be briefly or clearly expressed in words. Therefore, a course in general zoology has for aims training in the use of the English language, organization and drawing.

THE CONCLUSION

In the conclusion the organized data and its relation to some logical principle is discussed; and inferences are drawn involving cause and effect. The importance of the biological principle justifies the drudgery of the work. The drawing of conclusions from organized data is an aim in a course of general zoology.

INFORMATION

To understand himself and his environment is an aim too abstract for a student to grasp without the background that the course is designed to give. This aim is not apparent until the course has been completed. It is, therefore, necessary to consider a series of minor aims that come, to some extent, within the previous experience of the student, such as phases of morphology, physiology, behavior, evolution, heredity, etc. Since morphology is so much easier to treat in the laboratory, we are apt to center on it and so fail to impress the student with its relation to the real aim of the course.

An aim of a science course is to give training in how to do with a background of knowledge which will allow of a selection in the matter of action. An aim of a biological course is to give training in how to use eye, hands, and brain in the control of ourselves and our environment, with a background of knowledge that will allow of a selection of action.

AIM, INCENTIVE AND CONTENT

Aims, as outlined above, furnish little incentive for work. The ultimate object is too big a picture to be "interpreted" by one so close as a student in a laboratory class. The needed perspective can only be acquired after the course has been completed. Minor aims, clearly within the experience of the student, selected with a thought not only to the principal aims but also with the available material in mind, must be presented. These aims must seem to the student clearly important. Experience has shown that a combination of the problem method as illustrated in Hunter's "Problems in Civic Biology" and the project method now being worked out by teachers in the high schools gives the most science and information with the most incentive.

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PHYSICAL METHODS AND MEASUREMENTS, AND THE OBLIGATION OF PHYSICS TO THE OTHER SCIENCES

SEVERAL months ago there appeared in SCIENCE a brief article[1] by the present writer in which he advocates a carefully planned course in physical measurements, supplementing the beginning course in college physics, to suit the needs of students of the chemical, biological and the related sciences. In response to the article, there have been received more than twenty communications from scientific workers in the colleges and in the industries, relative to the subject. They are unanimous in expressing their agreement with the views stated. At the same time they express doubt as to the existence of a college physics department which will offer a course designed especially for the science student outside of physics.

To those who are working in the various experimental sciences, or who are in position to see and judge the work in numerous laboratories, it is evident that the need for better training in physical principles, methods and measurements is an urgent one.[2] To secure evidence of the truth of this contention, one needs only to obtain the views of the heads of industrial laboratories in which the services of many science graduates of our colleges are required. Or let the physicist who is—and, more than anyone else, should be—interested, interview his scientific colleagues to learn how much the lack of familiarity with physics may have proved a handicap in their own work or in that of their graduate students. There is concrete evidence in the report that some of the industries are contemplating or have already taken steps towards establishing training schools for their young technical graduates, to give them the sort of training which the colleges should have provided.

It seems to me that here is clearly an obligation upon the physicist. It is also an opportunity. It is an opportunity in the sense that if he could be instrumental in providing the coming generation of scientific workers with adequate training in physics, greater progress in science might assuredly be looked for. This not because physics is at all more potent than the other sciences in exploring the unknown, but because it is so fundamental. At every turn we encounter a physical phenomenon; every experiment that is planned involves some sort of measuring instrument, some form of control device, some physical method. Physics plays such an obviously important part in the great majority of researches that it leads one to wonder why

[1] SCIENCE, N. S., 50, 199, 1919.

[2] On this point "Chemical and Metallurgical Engineer" says: ". . . we know from experience that an adequate familiarity with them (physical methods) is far too often lacking among young chemists, and Mr. Klopsteg's proposal would seem to cover an important gap."

this phase in the education of our science students has received so little attention. It leads one also to wonder why so little attention is paid to methods of instruction and to the proper coordination of the college science courses.

I have said that it is the physicist's obligation to see that the science student—in chemistry, in medicine, in biology, in psychology—may secure the fundamentals not only of general physics, but of the physical measurements and methods which will apply to his work. The obligation logically belongs to physics because the courses are courses in applied physics, and because the work of organizing such courses would unquestionably be easier for the physicist than for the non-physical scientist to whom physics is unfamiliar ground. The latter could not be expected to make a good teacher in physical measurements.

There are obstacles to the realization of what has been proposed. Some of them appear formidable, but where the results to be achieved seem so full of possibilities, let us hope that they may not be insurmountable. Some of the obvious difficulties may be mentioned. The method for their elimination is not so obvious.

Because of the rapid development of physical methods within recent years, and their rapidly increasing applications, their importance may not have impressed itself fully upon those in charge of the student's training. Perhaps they have thus come to value the time spent by the student upon courses in his own field as far greater than equal periods in the physical laboratory. Among their own specialties they see so many things which the student must have before he is fit for his degree. But is not this a biased view?

Let us suppose that a student has received a degree in chemistry, but that his work did not include several subjects in chemistry which might have value to him later. He takes a position in a chemical industry. He is surrounded by chemists; has access to an excellent library; his interest in chemistry is foremost among his interests. Under these circumstances his educational equipment will not long remain deficient in the subjects which he did not get in college. On the other hand, suppose—and this is usually the case—that he lacks knowledge of physical methods and experience with physical instruments. His environment and his interests make it exceedingly difficult to acquire this knowledge and experience, because he is now quite upon his own resources.

Conditions are much the same with the graduate in almost any science, continuing in post-graduate work. Although he is in position to request the information he wants, by applying to the physics department, the physicists have so many of their own problems that, unless his request is a very moderate one, he will have indifferent success in securing the needed information.

In both the cases just suggested, much time and effort would be saved, with better results, had a well-planned course been available for the student. The college physics laboratory is the place where such training should be given. Failing in this, the colleges must expect to see the industries adopt the alternative of usurping one of the functions of the college. This raises the question: why is not such a course of training in physics offered by every physics department? The answer is fairly apparent.

A course like the one suggested, in order to measure up to its fullest possibilities, would require painstaking preparation by the instructor having it in charge. It would be necessary for him to have an understanding of the problems. He would need to appreciate most fully that, in this particular case, physics is a means to an end, and that the student is interested in physics solely for what it can do for his own, more interesting science. To secure the necessary understanding of the problems, he might have to spend considerable time in going through the various scientific journals, to see where and how physical methods are used. Thus he would be compelled to sacrifice some of the time which otherwise he might devote to research. But, in giving up some of his research, would he

not actually be rendering a greater service to science than he would in following the alternative course? Yet there are probably few physicists, engaged in teaching and research, who have more than a passing interest in the possible applications of physics to the other sciences. Perhaps it is only natural that the motive of early results of their work, in the form of publications, should far outweigh the motive of results greater and more lasting, but somewhat intangible and long deferred.

Under existing conditions there is undoubtedly another source of discouragement to the physics instructor who would otherwise gladly develop such a course. This is the tendency on the part of our educational institutions to make advancement in rank and salary depend almost entirely upon productive scholarship, sometimes measured in terms of volume rather than quality. Excellence in teaching and conscientious work upon a course of the kind here advocated would hardly be considered productive. The instructor, in doing such work, would be making a real sacrifice to the cause of science. Few can afford to make sacrifices of this kind.

Whatever the solution of the difficulties which have been pointed out, it will probably be satisfactory and acceptable to our educational institutions only if it comes as the result of cooperation on a large scale among the various sciences. Although the responsibility for making physics available in the manner suggested seems to me to belong to physics, the initiative in demanding of physics the kind of training that is wanted belongs to the other sciences. It is their duty to outline to physics what they need, and after the courses have been made available, to maintain an active interest in rather than a passive attitude towards them. And the common motive must be the vision of the significant but, perhaps, little appreciated contributions, through such efforts, to the advancement of science. To find the answer to the problems which are brought up by this aspect of the problem of properly training our science students seems a task worthy of a body like the American Association for the Advancement of Science. The accomplishment of such a task would give a new and fuller meaning to the name of this great organization.

Paul E. Klopsteg

Leeds & Northrup Company,
Philadelphia, Pa.

SCIENTIFIC EVENTS

THE OHIO COLLEGE AND EXPERIMENT STATION

In 1917 the College of Agriculture of the Ohio State University and the Ohio Agricultural Experiment Station entered upon a closer cooperation in their respective fields of work by the appointment of C. G. Williams, chief in agronomy at the station as non-resident professor of farm crops at the college; of Professor J. B. Park and Firman E. Bear, of the college as honorary associates, respectively, in agronomy and soils at the station, and of G. W. Conrey, instructor at the college as assistant in soils at the station. In 1918 Professor Herbert Osborn, of the college, was appointed honorary associate entomologist of the experiment station, and H. A. Gossard, chief in entomology at the station, was appointed non-resident professor of entomology at the college. In March, 1920, C. C. Hayden, chief in dairying at the station was appointed non-resident assistant professor at the college, and Professor Oscar Erf, of the college, was appointed honorary professor in dairying at the station.

In the actual working out of this cooperation the specialists at the experiment station's work by counsel, by lectures at the field meetings held by the station, and by conducting special lines of research which are reported in station bulletins.

The station's field experiments are widely scattered over the state, in order to bring under observation the various soil types and different industries, and these experiments are visited by the higher classes in agriculture at the college.

THE LOUISIANA ENTOMOLOGICAL SOCIETY

At New Orleans a meeting was held on March 5 to discuss the organization of an entomological society or club. The meeting

was called by Mr. Edward Foster, who had received assurances of support from about twenty-five entomological workers. Ten persons were present. They heartily endorsed the plan, and favored the organization of a society to be known as the Louisiana Entomological Society, to be domiciled at the Natural History Building of the Louisiana State Museum, Jackson Square, New Orleans. A committee on constitution was elected, and the next meeting was placed at April 2.

On that date the first regular meeting was held and the constitution was adopted. The following officers were elected: President, Mr. Edward Foster, state nursery inspector; Vice-President, Professor O. W. Rosewall, professor of entomology, Louisiana State University; Secretary-Treasurer, Mr. T. E. Holloway, of the U. S. Bureau of Entomology. An executive committee composed of the officers with the addition of Messrs. O. K. Courtney, of the Federal Horticultural Board, and Charles E. Smith and T. H. Cutrer, both of the U. S. Bureau of Entomology, was provided. It was decided that meetings are to be held on the first Fridays of February, April, June, October and December, the June meeting to be a Field Day, and the December meeting to be the annual meeting. The dues were placed at $1.00 per annum. Any person interested in the science of entomology is eligible for membership.

Mr. Robert M. Glenk, curator of the museum, very kindly placed at the disposal of the society a large and well-lighted lecture room, library and laboratory space, a moving picture outfit, and financial assistance in publishing the proceedings of the society.

T. E. HOLLOWAY,
Secretary-Treasurer

THE SOUTHWESTERN GEOLOGICAL SOCIETY

AT the annual meeting of the Southwestern Geological Society held at Dallas, Texas, on March 19, Robert T. Hill of Dallas was reelected president of that organization. Other officers elected were Charles E. Decker, of the University of Oklahoma, and William F. Kennedy, vice-presidents; Ellis W. Shuler, of the Southern Methodist University of Dallas, secretary, and R. B. Whitehead, treasurer. Members of the council are John A. Udden, Jerry Newby, Dr. H. P. Bybee, of the University of Texas, W. E. Wrather and D. W. Ohern.

Following the meeting the annual dinner was held in the roof garden of the Adolphus Hotel. More than 100 members of the society were present. Dr. George Otis Smith, of Washington, D. C., director of the United States Geological Survey; Dr. I. C. White of Morgantown, W. Va., president of the American Association of Petroleum Geologists were guests at the dinner.

This organization now numbers over 130 members and is doing much good in getting together the various geological workers in the southwest.

THE AMERICAN ELECTROCHEMICAL SOCIETY

THE American Electrochemical Society held its thirty-seventh meeting at Boston and Cambridge on April 8, 9 and 10. The members were welcomed by Professor H. P. Talbot, of the Massachusetts Institute of Technology. The annual address by the president, Dr. Wilder D. Bancroft, of Cornell University, lieutenant-colonel in the United States Army, was on "Contact Catalysis." It was followed by a symposium of "Colloid Chemistry."

Summarizing the report from the board of directors, the secretary, Professor J. W. Richards, said that the directors had protested against the abolition of the Chemical Warfare Service. The membership of the association has been materially increased during the year; it was 1,903 on January 1, 1919, and 2,209 on January 1, 1920, and is now 2,307. The treasury of the organization also is in a healthy condition, with $13,000 invested, largely in government bonds, and $4,000 cash assets.

Officers have been elected as follows: President, Walter S. Landis, chief technologist of the American Cyanamid Company of New York; vice-presidents, Dr. John A. Mathews, president and general manager of the Halcomb Steel Company of Syracuse.

N. Y., Lewis E. Saunders, vice-president of the Norton Company in Worcester, and Arthur T. Hinckley, chemist for the National Carbon Company at Niagara Falls, N. Y. Managers elected were Dr. Colin G. Fink, research director of the Chile Exploration Company of New York; Acheson Smith, vice-president and general manager of the Acheson Graphite Company of Niagara Falls, and H. B. Coho of the United Lead Company of New York; treasurer, Pedro G. Salmon, of Philadelphia, and secretary, Dr. Joseph W. Richards, professor of metallurgy at the Lehigh University, Bethlehem, Pa.

FIFTIETH ANNIVERSARY OF THE WISCONSIN ACADEMY

The celebration of the fiftieth anniversary of the founding of the Wisconsin Academy of Sciences, Arts and Letters will be the occasion of an important gathering at the University of Wisconsin on April 23. Professor T. C. Chamberlin, professor emeritus of geology at the University of Chicago, will give an address on "The founding of the Wisconsin Academy of Sciences, Arts and Letters," at an all-university convocation in the morning. Professor Chamberlin is one of the two or three living members who helped to establish the academy in 1870 for the purpose of preserving the scientific studies of the state. He was then professor of science at Whitewater Normal School. He was president of the University of Wisconsin from 1887–92, when he became professor of geology at the University of Chicago. The regular business meeting of the academy will be held in the morning, April 23, an all-university convocation will be held in the afternoon, and a banquet in the evening.

President E. A. Birge, of the University of Wisconsin, will preside at the afternoon meeting. Professor John M. Coulter, of the University of Chicago, will speak on "The relation of the local academy to the national organization," and Professor C. E. Allen, of the University of Wisconsin, will speak on "The proposed plan of affiliation of the local academies with national organizations."

The Wisconsin Academy was the first important means in the state of gathering scientific material and has preserved it in annual volumes, published at state expense. An anniversary volume of the proceedings, containing the papers of the members, will be published as the twenty-first volume of the *Transactions* of the academy.

A bronze medal commemorating the 50th anniversary of the founding of the academy is to be struck for the anniversary meeting. The medal will bear on its face the portraits of Dr. Increase A. Lapham, pioneer archeologist and antiquarian, Philo R. Hoy, naturalist and antiquarian whose collection of birds is in the Racine Public Library, George W. Peckham, authority on certain groups of spiders whose collection of the Attidæ species is in the Milwaukee Public Museum, Professor R. D. Irving, geologist and at one time head of the U. S. Geological Survey in the northwestern states, and Professor William F. Allen, authority on Roman history and antiquities. All were prominent in the early history of the academy. Under the portraits will appear the words, "Wisconsin Academy of Sciences, Arts and Letters, 1870–1920, Natural Species Ratioque." The obverse will bear the figure of Minerva, holding the lamp of learning, and the words "Naturæ Species Ratioque."

SCIENTIFIC NOTES AND NEWS

Dr. John Alfred Brashear, of Pittsburgh, distinguished as a maker of astronomical and physical instruments and an astronomer, died on April 9, in his eightieth year.

At the recent commemoration day exercises at the Johns Hopkins University, a portrait of Dr. J. Whitridge Williams, dean of the medical school, was presented to the university by Professor William H. Welch, and a portrait of Dr. Florence R. Sabin, professor of histology, by Professor William H. Howell.

The National Institute of Social Sciences, at its annual meeting on April 22, will confer a gold medal on Dr. Alexis Carrel, of the Rockefeller Institute for Medical Research.

Dr. John W. Churchman, professor of surgery at Yale University, who had previously been made officier de l'instruction

publique by the French government, has been named officier d'Academie (silver palms). The decorations are in recognition of work done as Medecin-chef of Hôpital militaire 32 bis. during 1916.

SIR JOSEPH LARMOR, of the University of Cambridge, has been elected a corresponding member of the French Academy of Sciences in the section of geometry.

PRESIDENTS of sections of the British Association have been appointed as follows: A (Mathematics and Physics), Professor A. S. Eddington; B (Chemistry), Mr. C. T. Heycock; C (Geology), Dr. F. A. Bather; D (Zoology), Professor J. Stanley Gardiner; E (Geography), Mr. J. McFarlane; F (Economics), Dr. J. H. Clapham; G (Engineering), Professor C. F. Jenkin; H (Anthropology), Professor Karl Pearson; I (Physiology), Mr. J. Barcroft; K (Botany), Miss E. R. Saunders; L (Education), Sir Robert Blair; and M (Agriculture), Professor F. W. Keeble. As has already been announced Professor W. A. Herdman will preside over the meeting which opens at Cardiff on August 24.

DR. C. G. STORM, formerly lieutenant colonel, Ordnance Department, U. S. A., has resigned as assistant director of research with the Trojan Powder Co., Allentown, Pa., to accept the position of professor of chemical engineering in the Ordnance School of Application, Aberdeen Proving Ground, Maryland, and will also be engaged in research work on explosives and other ordnance materials.

MR. SHERMAN LEAVITT, formerly professor of chemistry and agriculture in Illinois College, Jacksonville, Ill., has become food chemist for the War Department, stationed in the Bureau of Chemistry laboratory at St. Louis.

DR. EDWIN LINTON, professor of biology in Washington and Jefferson College, having reached the age of sixty-five years, will retire at the end of the present college year. He expects to devote his time to research work.

PROFESSOR HENRY PARKER MANNING, of the department of mathematics of Brown University, has resigned. Professor Manning has been connected with Brown University for twenty-nine consecutive years.

PROFESSOR ORA MINER LELAND, of the faculty of civil engineering at Cornell University, has resigned his professorship and taken a position with the J. G. White Company of New York.

MR. H. DEWITT VALENTINE has resigned from his position as instructor in chemical engineering at the University of Wisconsin, Madison, Wis., and is now retained as chemical engineer and bacteriologist by the Ozone Company of America, Milwaukee, Wis.

PROFESSOR ERNEST MERRITT lectured recently on "Methods used for the detection of submarines" before the Cornell chapter of the Sigma Xi. During the war Professor Merritt conducted investigations that proved of great value in diminishing the danger of submarine attack.

PROFESSOR C. F. HOTTES gave the address before the Illinois chapter of Sigma Xi, at the meeting of March 17. The subject of the address was "Algæ as rock builders."

DR. LOUIS A. BAUER gave the evening lecture at the joint meeting, held in Columbus on April 2, of the Ohio Section of the Mathematical Association of America, the Ohio College Association and the Ohio Society of College Teachers of Education. His topic was "The deflection of light observed during the solar eclipse of May 29, 1919, and its bearing upon the Einstein theory of gravitation," illustrated by lantern slides. He also gave public lectures on "The solar eclipse of May 29, 1919 and the Einstein theory" at Ohio State University, April 3, at Ohio Wesleyan University, April 5, and at the College of Wooster, Wooster, Ohio, April 6.

A COURSE in fractures is being given at the Cornell Medical College, during April by Dr. Joseph A. Blake, Dr. George W. Hawley and Dr. James N. Hitzrot Five. Dr. Alexis Carrel will also give one lecture. Other exercises will be held by Dr. H. H. M. Lyle, Dr. Burton J. Lee and Dr. John C. A. Gerster.

THE annual initiation of the Columbia Chapter of Sigma Xi was held on Friday evening, April 9, at Columbia University.

The initiation was followed by a dinner for which the following program was arranged:

Toastmaster: Marston T. Bogert, professor of organic chemistry.

Engineering research: George B. Pegram, dean of the schools of mines, engineering and chemistry.

Research in forest products: Samuel J. Record, professor of forest products, Yale University.

Science in the industries: M. C. Whitaker, vice-president of the U. S. Industrial Alcohol Company.

Applied psychology: E. L. Thorndike, professor of educational psychology.

The new members: Stephen P. Burke.

At the meeting of the Executive Committee of the Massachusetts Society for Mental Hygiene held March 9, 1920, the following resolution was adopted:

The directors of the Massachusetts Society for Mental Hygiene desire to express their deep sorrow and their great sense of loss in the death of Professor Elmer Ernest Southard. To many of them he was a warm personal friend whom they will sorely miss. His great natural abilities, his extraordinary powers of insight and deduction were most valuable to the society in which he took an active and stimulating interest.

The directors feel that they have lost not only a most valuable adviser and colleague but one on whose sympathy and friendship they could always depend.

Dr. George Egbert Fisher, professor of mathematics in the University of Pennsylvania, died on March 28, aged fifty-seven years. The following resolutions have been passed by faculties of the university:

The faculties of the college, the graduate school and the school education have learned with profound sorrow of the death of George Egbert Fisher, professor of mathematics and sometime dean of the college.

Professor Fisher's connection with the faculty dates from 1889, when he was appointed assistant professor of mathematics.

Earnest in purpose, lofty in ideals, a patient and inspiring teacher, he invariably won and held the respect and love of his students.

We of the faculty wish to bear testimony to our appreciation of the profound scholarship of our departed colleague, and to our recognition of his exceptionally deep and abiding love for mathematics. It was always his aim to foster a more general interest in this subject. We would testify also to his ready and sympathetic cooperation in all that was for the best interests of the university.

Sir Anderson Stuart, professor of physiology in the University of Sydney since 1883 and the dean of its medical faculty, died on February 29, aged sixty-four years.

The magnetic survey vessel, *Carnegie*, arrived at St. Helena Island, on March 30. She will sail again early in April, bound for Capetown.

The American Medical Association, as has been already noted, will hold its seventy-first annual session in New Orleans, beginning on April 26. This is the fourth time the association has convened in New Orleans. The twentieth annual session under the presidency of Dr. William Owen Baldwin in 1869 aided in bringing the members of the medical profession in the south into cordial relationship with the national association following the Civil War. In 1885, under the presidency of Dr. Henry F. Campbell, the thirty-sixth annual session was held in New Orleans. In 1903 the association met in the city in its fifty-fourth annual session under the presidency of Dr. Frank Billings. The present meeting will be opened under the presidency of Dr. Alexander Lambert, of New York, and Dr. William C. Braisted, surgeon-general of the U. S. Navy, will be inducted into the office of president.

UNIVERSITY AND EDUCATIONAL NEWS

The legislature of the state of Mississippi has passed a bill appropriating the sum of $350,000 for a new building for the University of Mississippi, to house the department of chemistry and the school of pharmacy.

Dr. Arthur Twining Hadley, since 1899 president of Yale University, has presented his resignation, to take effect in June, 1921, when he will have reached the age of sixty-five years.

Albert W. Smith, dean of Sibley College of Mechanical Engineering, Cornell Univer-

sity, has been selected by the trustees' committee on general administration to be acting president of the university until a permanent successor to Dr. Schurman is appointed.

THE professorship of electrical engineering at Lafayette College, made vacant by the resignation of Professor Rood, who left Lafayette to go to the University of Illinois, has been filled by the appointment of Professor Morland King, of Union College, as associate professor of electrical engineering.

DR. WALTER K. FISHER, of the department of zoology at Stanford University, has been promoted to an associate professorship.

DR. MAX MAILHOUSE has resigned as clinical professor of neurology in the Yale School of Medicine, his resignation to take effect at the close of the present college year.

DISCUSSION AND CORRESPONDENCE

A SUGGESTION AS TO THE FLAGELLATION OF THE ORGANISMS CAUSING LEGUME NODULES

A VERY interesting note by Hansen on the flagellation of the legume nodule organisms (Rhizobium) appeared recently in this journal.[1] There has been a dispute for some time as to whether these bacteria have one or several flagella. Burrill and Hansen not long ago[2] claimed that they are monotrichic organisms, whereas various other investigators, including the present writers,[3] have observed peritrichic flagella. Hansen now says that he, too, has found peritrichic flagella on cultures obtained from clover, vetch and alfalfa, and calls attention to the fact that his earlier studies had been on organisms from cowpea and soy bean. Hence he suggests that there may be two different groups, one peritrichic and the other monotrichic. It is, indeed, generally recognized that the organisms of cowpea and soy bean differ from the other varieties of *Rhizobium* in certain cultural features, primarily in respect to vigor of growth.

Hansen's suggestion is very interesting, but does not explain all the facts that have been observed. Wilson[4] has found peritrichic flagella on cultures of the soy bean organism. To be sure, as insisted by Hansen, Wilson has not published any photomicrographs; but the statement he makes is definite and no one need question it. We have seen one of Wilson's microscopic preparations (soy bean organism) and also one of Hansen's (cowpea organism); and find four or five flagella on some of the bacteria in Wilson's preparations, but only one each on those in Hansen's.

Upon enquiry we find that Wilson's cultures were sometimes as old as 28 days at the time of staining; while it appears from Burrill and Hansen's paper that their preparations were only a few days old. In this connection it is an interesting fact that a certain organism (belonging to a different group) studied in this laboratory was found to have a single polar flagellum when a few hours old, but two or three polar flagella when a day or more old. This naturally raises the question whether the cowpea and soy bean organisms may not be monotrichic in young cultures and peritrichic when they are older. This suggestion is further borne out by the fact that Hansen found (as shown by statements in his text and by his photomicrographs) the single flagellum to be attached at the corner or even at the side more often than exactly at the pole. This is just what would be expected if it were a matter of chance which one of the peritrichic flagella developed first in a young culture.

Ever since the appearance of Burrill and Hansen's paper we have wanted to investigate the truth of the matter. As we have not had the chance to do so, we take this occasion to put the idea in print that any one else inter-

[1] Hansen, Roy, "Note on the flagellation of the nodule organisms of the Leguminosæ," SCI., N. S., 50: 568–569, 1919.

[2] Burrill, T. J., and Hansen, R., "Is symbiosis possible between legume bacteria and non-legume plants?" Ill. Agr. Exp. Sta., Bul. 202, 1917.

[3] Breed, R. S., Conn, H. J., and Baker, J. C., "Comments on the evolution and classification of bacteria," *Jour. Bact.*, 3, 445–459, 1918.

[4] Wilson, J. K., "Physiological studies of *Bacillus radicicola* of soybean (*Soja* Max., Piper) and of factors influencing nodule production," Cornell Agr. Exp. Sta., Bul. 386, 1917.

ested in this rather puzzling question may study it to see whether there is anything in the theory suggested here.

H. J. Conn,
R. S. Breed

Agricultural Experiment Station,
Geneva, N. Y.

PENSIONS FOR GOVERNMENT EMPLOYEES

The American Association for Labor Legislation calls attention to the very serious evils arising from the lack of a pension system in the government bureaus at Washington. They say: "It is now reported that of a total of 878 employees in one federal bureau in Washington, 303 are over 65 years old, 104 over 75, and 29 over 80. The Treasury Department alone has 1,000 aged who average only 25 per cent. efficiency—1,000 drawing full pay for work that could be done by 250."

This is a matter which concerns scientific men. I remember several years ago calling on one of the most eminent zoologists in the National Museum. I found that he was writing all his letters by hand, because the stenographer assigned to him was too old to do the work. He explained that of course he could not, or would not dismiss her; but as a result he was left without the assistance he should have had. I recall a scientific assistant, retained by a bureau long after he had ceased to be able to do anything of value, but required to spend his days at his desk. No one would have thought of turning him away unless he could be adequately provided for. The effect of these conditions on the progress of science is obvious and lamentable.

It appears that there is now a bill before Congress, providing for retirement on part pay at 65, the employee contributing 2½ per cent. of wages, the government the rest. It should certainly be supported.

T. D. A. Cockerell

University of Colorado,
March 1, 1920

THE RECENT AURORAS

The Weather Bureau is compiling observations of the auroras of March 22–23, 23–24, and 24–25, 1920, as seen in the United States, or elsewhere, with a view to publishing a detailed account of this remarkable display in the March, 1920, issue of the *Monthly Weather Review*. It is hoped that those who observed an aurora on any of the dates mentioned will notify the bureau, and if details were noted will send copies of their notes. Information about any display which may be seen on April 18, 27 days after the brilliant night in March, or auroras observed on other dates in 1919 or 1920 will also be appreciated. Communications should be addressed to "Editor, Weather Bureau, Washington, D. C.," and should reach Washington by the end of April.

Charles F. Brooks,
Meteorologist-Editor

QUOTATIONS

CIVIL SERVICE PENSIONS

After years of half-hearted consideration Congress seems about to pass a bill for the retirement and pensioning of employees in the federal service. It will be applicable only to those in the classified service, about 300,000 in all. It is a measure of justice and at the same time a measure of economy, for the government hasn't been heartless enough to turn the superannuated loose. Thousands of them retain their places, but do little or no work.

The government retires employees in the military and kindred services. It ought to set a similar standard for faithful civil employment. The retirement age in the army is sixty-four, and in the navy sixty-two. Taking into consideration the easier conditions of civil employment, the bill which has just passed the Senate fixes seventy as the civil retirement limit. The allowances will vary according to length of service, from thirty years down to eighteen years. Persons disabled through disease or injury in the line of duty may be retired before reaching seventy.

Another distinction is to be made between civil and military beneficiaries. An annuity assessment of 2½ per cent. will be levied annually on the salaries of civil employees until a retirement fund is accumulated. This assess-

ment is expected to pay about half the cost of the system.

There are now about 9,000 superannuated civil servants, most of them in Washington. They will go out in a body. The retired list will eventually reach about 30,000. But with the moderate annuities allowed, the maximum being $720, the government's experiment will cost little. The efficiency of the working force will be increased. More work will be done by a smaller staff.—*New York Tribune*.

THE ECOLOGICAL RELATIONS OF ROOTS[1]

PROFESSOR J. E. WEAVER has recently put out an extensive study on roots which comprises observations made in the "prairies of eastern Nebraska, chaparral of southeastern Nebraska, prairies of southeastern Washington and adjacent Idaho, plains and sandhills of Colorado, the gravel-slide, the half-gravel-slide, and forest communities of the Rocky Mountains of Colorado." The roots of about 140 species are described. The species include shrubs, grasses and other herbs. With a description of the roots is presented a characterization of the physical environment. Among other features of the latter are given the rainfall and evaporation, the temperature of the air and to a certain extent the temperature of the soil and its moisture content. The work is abundantly illustrated with root maps and reproductions of photographs.

The study by Weaver is a continuation and an extension of his well-known work along similar lines. It is wholly observational and must be considered as constituting a very noteworthy contribution to our knowledge of the habits of roots. It touches elbows with so many features associated with the habits and relations of the plants of the regions studied that it is not practicable to present a summary of the results. However, it may not be amiss to point out certain of the more interesting of the facts presented. For detailed information the reader is referred to the work itself.

[1] Carnegie Institution of Washington, Publication No. 286, 1919.

Without attempting to summarize exactly it can be said that in a general way the root systems of plants in the communities studied are fairly characteristic. Thus in the prairies and the plains also the roots usually extend widely and penetrate deeply, but more deeply in the former than in the latter community. And the tap root is the principal feature. In the sandhills the roots of several species are confined to the surface 2 feet, and practically all show a striking "profusion of long, widely spreading laterals in this surface-soil stratum." In the gravel-slide and forest communities of the Rocky Mountains, adjoining Colorado Springs, the roots are confined to the surface 18–24 inches. In the half-gravel-slide, however, the root penetration is deeper, although the root systems develop widely spreading shallow roots as well. Finally, in the case of species growing in more than one habitat it was found that in most cases the direction and extent of roots developed corresponded very well to the "community root habit."

Roots of different species may be so unlike in the extent and direction of their development, as well as in other morphological features, as to be readily identifiable. They also undoubtedly exhibit quite as distinct physiological characteristics, although such can not be told from inspection. For these reasons a knowledge of the roots of any habitat gives a very good clue to many of the striking features of that habitat, just as the nature of the shoot of a plant reveals much regarding the subaerial conditions under which it has developed. It consequently follows that through the study of roots of native plants, much can be learned in advance of culture of the possibilities of agricultural lands. Such, however, is a possible economic application of this and similar root studies and was suggested, but not developed, by the author.

The most striking root figure by Weaver is that of *Ipomœa leptophylla* of the sandhills about forty miles southeast of Colorado Springs. The soil absorbs all of the rain and there is practically no run-off. Through a

rapid drying out of the surface sand a dust mulch is formed which retards effectively further water loss from the soil. At a depth of a few inches the soil is always moist, and, from data given for another locality with similar soil, it would appear that the moisture may be fairly uniform to a depth of six feet. Exact data, however, as regards this feature are wanting. Of 19 sandhill species whose roots were studied, 8 have roots which are entirely or nearly confined to the first two feet of soil, and of the balance all save one have the greatest root development at this depth. The roots of *Ipomœa* were the most extensive of those of any species in the community, or, for that matter, apparently the most extensive of any observed during the course of the study. The block of soil included within their reach was approximately fifty feet in diameter and over ten feet in depth. The roots were fairly well distributed throughout except only in the surface foot from which they were largely wanting. Another feature of the root was the enlarged and tapering tap which was about eight inches in diameter a foot beneath the surface and the enlarged portion of which was about three feet long. The enlarged tap of *Ipomœa* constitutes an important reservoir for food and water storage.

Weaver finds in general that in the communities studied the most striking root characters, at least so far as the gross morphology is concerned, are intimately related to the moisture conditions of the soil. Where, for example, the uppermost soil layers only are moist, there is a marked development of laterals. In the event the soil carries moisture to a considerable depth, as on the prairies, deep root penetration in many species occurs. Apparently he does not find soil temperatures or soil aeration limiting factors in root penetration although that such may be the case in certain instances seems to the reviewer not unlikely. For example, the roots of *Opuntia fragilis* do not appear to attain to a depth greater than fifteen inches, and it is usually considerably less than this. The roots of *Yucca* are also for the most part shallowly placed. And, finally, in the prairies as regards penetration, there is a fairly well-marked stratification of the roots. It may be as suggested in the case of plains species that the "well developed system of shallow, widely spreading laterals is undoubtedly a response to the moisture in the surface soils resulting from frequent light summer showers." However, in the opinion of the reviewer, the possibility that the root-temperature or the root-soil aeration relation may also be of importance is by no means excluded. The various root relations are so closely interwoven that any one can only be evaluated when the rest are so far as possible controlled. And this requires exhaustive experimentation, which was not within the scope of the present study.

The extremes as regards root penetration appears to be met in the case of *Opuntia fragilis,* of the plains, on the one hand, and possibly, *Lygodesmia juncea,* of the Nebraska prairies. In *Opuntia* most of the roots lie within one to three inches of the surface of the ground, with an extreme penetration of eight to fifteen inches. While the roots of *Lygodesmia* have been found to attain a depth exceeding twenty feet seven inches. In the latter instance the soil is loess, with uniform physical properties, and is very favorably for deep root penetration. This well authenticated penetration is sufficiently deep, but it is of interest to note the observation given in Merill[2] that "Aughey has found roots of the buffalo berry (*Shepherdia argophylla*) penetrating the loess soils of Nebraska to a depth of fifty feet."

In a work so well done it seems captious to allude to a feature not by itself of fundamental importance. However that may be, it seems to the reviewer unfortunate that the English and the metric systems of measurement, especially, are both used throughout the study. Consistency in this regard would surely meet more general approval.

W. A. Cannon

Desert Laboratory

2 "Rocks and Rock Weathering," p. 181.

SPECIAL ARTICLES

THE TERTIARY FORMATIONS OF PORTO RICO[1]

In 1914, the New York Academy of Sciences commenced a scientific survey of Porto Rico and the Virgin Islands. The outcome of this work has been a series of reports, covering geology and other branches of investigation. The important geological contributions which have been published are:

1. "A Geological Reconnoissance of Porto Rico," by C. P. Berkey, *Ann. N. Y. Acad. Sci.*, Vol. XXVI., pp. 1–70, 1915.

2. "Geology of the San Juan District," by D. R. Semmes, N. Y. Acad. Sci., Sci. Surv. of P. R. and the Virgin Islands, Vol. I., pt. 1, pp. 33–110, 1919.

In the summer of 1916, the writer, working under the auspices of the New York Academy of Sciences, made a detailed study of the northwestern portion of the island (Lares District). The results of that survey, together with the conclusions of Berkey, Semmes, and other geologists who have worked in Porto Rico, are outlined in the present paper.

General Outline.—R. T. Hill[2] showed that the central core of Porto Rico is made up of a volcanic complex, with sediments of Cretaceous age, and with coastal belts of a white limestone (Pepino Formation) of Tertiary age. In 1915, Berkey[3] showed that the central mountainous complex (Cretaceous) is overlain unconformably by the Tertiary limestones of the north an south coasts (Arecibo Formation). The Tertiary in turn is overlain disconformably by a limited coastal belt of solidified dune sands and beach deposits (San Juan Formation) of Pleistocene to Recent age. He called the Cretaceous complex the "Older Series"; the Tertiary and Pleistocene formations the "Younger Series," and pointed out that the unconformity separating these two series is a profound one, the chief break in the geologic succession of the island. The work of Berkey, Semmes, and others has added much to our knowledge of the geologic structure of the island, especially of the Older Series rocks. However, the Younger Series is best developed in the northwest corner of the island, and it was not until work here had been completed that a detailed statement of the Tertiary formations could be made.

The Tertiary Formations.—The Tertiary formations are essentially a series of white limestones, part massive or reef-like, part well stratified. The beds are for the most part undisturbed, and dip gently seaward at angles of 4° to 6° on the north coast, and 10° or more on the south coast. Except locally, where slumping or slight warping has occurred, or faulting (on the south coast) these dips represent the initial angles at which the beds were deposited.

The Tertiary formations were laid down upon a slowly subsiding old land surface of considerable relief. The valleys of this old land surface were invaded by the sea during the initial submergence, and in them were deposited gravel, sand, mud, lignitic clay, and marl. Such deposits, with their alternation of fresh water, brackish water, and marine fossil faunas, now form the basal shale member of the Tertiary groups of the north and south coasts. Compared with the overlying limestones, this basal shale is local in distribution, and very variable in thickness.

The maximum thickness of the Tertiary group in the northwest part of the island (Lares District) is nearly 4,000 feet. On the south coast, Berkey[4] estimates the thickness at 3,000 to 4,000 feet. Evidence obtained in the Lares District seems to show that these beds were never deposited vertically to any such thickness, but are somewhat analogous to the fore-set beds of a delta. The limestones represent a series of fringing reefs whose maximum growth was outward rather than upward. It is believed that at the period of maximum submergence in Tertiary time, the central mountain chain of the island was not submerged. During sub-

[1] Presented before the Geological Society of America, Boston meeting, December 29–31, 1919.

[2] Porto Rico, *Nat. Geog. Mag.*, Vol. X., pp. 93–112, 1889.

mergence there was a progressive overlap from west to east. Thus in eastern Porto Rico and Vieques Island, the uppermost formation of the Tertiary group lies directly on the Cretaceous.

Origin.—These Tertiary limestones have been referred to as coral reef limestones. This is misleading, for while corals are abundant in the lowest reef limestone of the group, the overlying limestones are made up chiefly of foraminiferal and molluscan shells.

The so-called "Pepino" or "Haystack" hills (known as "Cock Pits" in Jamaica) are not individual reefs or reef-mounds, as might appear, but are the product of caving or slumping caused by an extensive underground drainage, aided by rapid surface solution. The result is a peculiar type of karst topography, seen on many of the islands of the West Indies, but nowhere so well developed as on the north coast of Porto Rico.

Subdivisions.—As a result of the work in the Lares District, the writer has made the following subdivisions of the Tertiary group of the north coast:

Arecibo Group	Quebradillas	limestone	—700- 875 feet
	Los Puertos	limestone	—550-1,000 feet
	Cibao	limestone	—250-1,000 feet
	Lares	formation	—350-1,275 feet
	San Sebastian	shale	—max. 700 feet

In this classification, the names introduced by Berkey[5] have been used wherever possible. The term "Arecibo," introduced by Berkey, is used because the earlier name, "Pepino formation," of R. T. Hill is a purely lithological and topographical term, and is therefore undesirable.

On the south coast, no detailed subdivision has been made, but the names "Ponce" limestone and "Juana Diaz" shale (basal member) introduced by Berkey, are sufficient. After a careful study and comparison of a large collection of Tertiary fossils from the north and south coast formations, the following correlation is made, and believed to be essentially correct:

[4] C. P. Berkey, *op. cit.*, p. 14.

[5] C. P. Berkey, *op. cit.*

North Coast	South Coast
Quebradillas limestone Los Puertos limestone	Upper Ponce (including Guanica) limestone
Cibao limestone Lares formation	Lower Ponce limestone
San Sebastian shale	Juana Diaz shale

Age.—T. W. Vaughan,[6] from a study of fossil corals collected by R. T. Hill in the upper San Sebastian shale and lower Lares formation, concluded that the age of the "Pepino formation" is Middle Oligocene (Antiguan). C. J. Maury,[7] from a study of molluscan fossils collected in Porto Rico in 1914 by C. A. Reeds, concluded that the Quebradillas limestone is of Lower Miocene (Bowden) age, and that the "Rio Collazo shale" (= San Sebastian) is Middle Oligocene (Antiguan). The writer, from a study of a large collection of molluscan fossils from the Lares District, agrees with these conclusions, but would place the Quebradillas limestone (= Bowden) in the Upper Oligocene, rather than Lower Miocene. This departure seems to be warranted by the abundance of *Orthaulax* (several species) and *Ostrea antiguensis* throughout the Quebradillas. Furthermore, there is no faunal hiatus or disconformity to be found anywhere within the Tertiary group of the north coast. The entire series is a structural unit, as Berkey pointed out.[8]

The ages assigned to the north coast formations are as follows:

7. San Juan formation	Pleistocene-Recent
.... Disconformity	
6. Quebradillas limestone (= Bowden)	Upper Oligocene
5. Los Puertos limestone	
4. Cibao limestone	Middle Oligocene (Antiguan)
3. Lares formation	
2. San Sebastian shale	
.... Unconformity	
1. Older Series	Upper Cretaceous

Bela Hubbard

[6] Bull. 103 U. S. Nat. Mus., p. 260, 1919.

[7] *Am. Jour. Sci.*, Vol. XLVIII., p. 212, 1919.

[8] C. P. Berkey, *op. cit.*, p. 15.

THE AMERICAN CHEMICAL SOCIETY. IX

An examination of Wisconsin oil of Monarda Punctata: Nellie Wakeman. (By title.) Following up the work on "A Possible New Terpene in the Volatile Oil of *Monarda Punctata*,"[5] reported upon at the New Orleans meeting of the American Chemical Society in 1915, another examination of the oil has been made. This study confirms in every particular the earlier report. The low boiling terpene fractions contain a hydrocarbon, $C_{10}H_{16}$, which yields a nitroso chloride melting at 89°. This in turn yields a nitrolpiperidide which melts at 198°–199° and a nitrolbenzylamide which melts at 103°. With aniline the nitroso chloride behaves like that of pinene, the regenerated hydrocarbon having a pinene-like odor, quite different from the original oil. The fraction boiling at 165°–168°, which gives the most abundant yield of nitroso chloride, exhibits the following physical constants at 20°. Specific gravity 0.8476; optical rotation + 4.48; index of refraction 1.4698. The low boiling nonphenol fractions also contain isovaleric aldehyde, identified by its p-nitro phenylhydrazone which melts at 108°–109°, also by oxidation to an acid and its determination as silver valerinate. The noncrystallizable phenol portion contains carvacrol, hitherto not known in this oil, identified by its phenyl urethane melting at 137°.

On hemoglobin, 1. Optical constants: Wm. H. Welker and Chas. S. Williamson. The absorption constants of hemoglobin from various species of animals were studied by means of the spectrophotometer. The hemoglobin was prepared by a method, which was more favorable for the removal of associated colloids than the older methods. Hemoglobin from the dog, ox, cat, chicken, guinea-pig, rat, sheep, horse, pig and man were studied. The results obtained would indicate that if there is any difference in the absorption constants of hemoglobin from different species, these differences are not sufficiently large to serve as means of identification of the species.

Analysis of pleural fluid from a case of chylothorax: Wm. H. Welker and Chas. S. Williamson. Quantitative analyses of pleural fluids obtained from cases of chylothorax are extremely rare in medical literature. The analysis of the fluid obtained from this case, follows:

	Per Cent.
Specific gravity	1.0199
Solids (total)	6.64
Ash (ignition at 750° C.)	0.85
Nitrogen (total	0.75
Nitrogen (non-colloidal)	0.02
Nitrogen (colloidal, calculated as protein)	4.56
Lipins (total)	0.79
Lipins (unsaponifiable)	0.75
Chlorin (calculated as NaCl)	0.73

Digestibility of avocado and certain other oils: H. J. Deuel and Arthur D. Holmes. (By title.) The experiments were carried on similarly to the previous ones in which the digestibility of about 50 different oils has been determined. With the exception of the avocado fat, the oils and fats included in this study incorporated in a special cornstarch blancmange or pudding were eaten with a simple basal diet (commercial wheat biscuit, oranges and sugar) which supplied only a very small amount of fat and tea or coffee was used according to personal preference. It was thought best to test the digestibility of avocado fat by serving the fruit as it grows with a simple basal ration very nearly fat-free, the avocado being eaten in such quantities that it supplied an amount of fat comparable with the fat consumed in other fat experiments. Weighings were made of all the food served and refuse remaining, the difference between the two representing amounts eaten. The fat of water-free feces was also recorded. Both food and feces were analyzed in order to determine the amounts of protein, fat and carbohydrate in each. The difference in the amounts of these constituents present in the food and in the feces was taken to represent the amounts of each actually utilized by the body. The estimated digestibility was avocado fat 82.5 per cent., capuassu fat 92.7 per cent., cohune oil 99.0 per cent., hempseed oil 98.5 per cent., palm-kernel oil 98.0 per cent., and poppy-seed oil 96.3 per cent. The digestibility of avocado fat is somewhat lower than that found for most fats and oils. While the intake of avocado fat varied somewhat with the different subjects, the data available is not sufficient to warrant any conclusions as to whether or not a smaller intake of avocado fat would have been more completely assimilated. The average amount of fat eaten daily in each of the experiments was: Avocado 90 grams, capuassu fat 40 grams, cohune oil 52 grams, hempseed oil 53 grams, palm-kernel oil 100 grams and poppy-seed oil 49 grams. The number of experiments re-

[5] Science, Vol. 42, p. 100.

ported in each group was 4 with the exception of hempseed in which three experiments were reported and poppy-seed in which 7 experiments were reported. The subjects reported no laxative effect in any of the experiments with the exception of slight disturbances with the capuassu fat which was similar to the disturbances caused by cocoa butter. The general conclusions are that these fats should prove valuable for food purposes and that cohune, hempseed, poppy-seed and palm-kernel oils are very completely assimilated by the body.

Experiments on the digestibility of entire wheat flour ground by various processes: C. F. Langworthy and H. J. Deuel. (By title.) It seemed advisable to determine what effect different methods of milling had on the digestibility of entire wheat flour so experiments were carried out with entire wheat flour ground in five different commercial processes. The different methods of milling used were: (1) A commercial roller mill, (2) roller mill of the Bureau of Chemistry, (3) burr stone mill, (4) steel burr mill, and (5) attrition mill. The experiments were conducted in the same manner as previous experiments of such a nature have been carried on by this office. The flour was incorporated in a ginger bread and fed with a basal ration of oranges, butter and sugar, and tea or coffee was used according to the individual preference. The general results from these experiments seemed to indicate that the finer the wheat is ground, the more completely the protein is absorbed while the percentage of carbohydrate absorbed remains nearly constant. Even in the most finely-ground flour, the protein was only 79 per cent. absorbed while in the case of highly-milled flour (*i. e.,* flour in which the bran has been removed), it has been found that it is about 88 per cent. digested. In the case of the flour milled on the stone burr and steel burr mills the digestibility of the carbohydrate was found to be 97 per cent. and 95.5 per cent. digested, respectively. The protein in each case was 79 per cent. digested. The digestibility of the flour milled on the attrition mill was 95.5 per cent. for the carbohydrate and 74.5 per cent. for the protein. With the commercial sample of roller-milled flour, 94 per cent. of the carbohydrate was digested and 70 per cent. of the protein, and with the sample prepared in the laboratory roller mill, the carbohydrate was 95 per cent. digested and the protein 71 per cent. Both the samples ground on a roller mill were considerably coarser than those ground on any of the other three mills. It is expected that a bulletin will appear shortly giving a summary of these experiments.

Adsorption of fat by fried batter and doughs and causes of their variations: Minna C. Denton and Edith Wengel. (By title.) The various ingredients of the dough exert varying effects upon fat absorption. The gluten of wheatflour, when acted on by hot fat of suitable temperature, tends to form a crust which prevents or hinders fat penetration; so the stiffer dough absorbs less fat, other things being equal. Sugar increases fat absorption very decidedly. Fat present as an ingredient of the dough, *greatly* increases the fat absorption. Egg, if not above 60 per cent. of the weight of the liquid (as is the case in doughnut recipes) does not lessen the fat absorption, but contrary to current opinion seems even to increase it somewhat. Many details of manipulation exert the most profound effects upon fat absorption. Length of time of frying and relative amount of surface exposed, are two of the most important. Crust formation is of the greatest importance. Any manipulation increasing volume (and consequently surface) increases fat absorption. Turning the cakes repeatedly as they fry increases fat absorption, because it promotes the exposure of a soft crust, to the hot fat. The influence of temperature upon fat-absorption (constant time, temperature 150° C. and 200° C.) is variable and depends entirely upon the consistency and ingredients of the dough. In practical cookery, however the time would be reduced at the higher temperature and this would lessen fat absorption. Temperature is important also because of its influence upon crust formation and upon expansion of the dough.

Charles L. Parsons,
Secretary

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